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ABSTRACT

In recognition that computers are becoming an integral part of science teaching, the British Department of Education asked the Royal Society of Chemistry to investigate the current use of microcomputers and microelectronics in teaching chemistry at the secondary school level. This document presents the results of that study. It includes: (1) an introduction and some general considerations for using computers in the chemistry classroom; (2) a discussion of software applications and an assessment of current areas of weakness in software production; (3) a listing of areas of the chemistry curriculum where software is available and can be used; (4) some guidelines for selecting hardware; (5) some implications for training teachers to use microcomputers; (6) a description of novel uses of microcomputers; and (7) a list of specific recommendations resulting from the study. A copy of the national survey questionnaire is included in the appendix. (TW)

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THE ROYAL SOCIETY OF CHEMISTRY

THE USE OF MICROCOMPUTERS IN SCHOOL CHEMISTRY

A report of a working group of the Royal Society of Chemistry to the Department of Education and Science

1986

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Burlington House Piccadilly London W1V 0BN

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C O N T E N T S

		PAGE
1	FOREWORD	4
2	SUMMARY	5
3	SCOPE OF THE STUDY	6
4	INTRODUCTION AND GENERAL CONSIDERATIONS	9
5	SOFTWARE	14
6	SOFTWARE AND THE SYLLABUS	18
7	HARDWARE	22
8	IMPLICATIONS FOR TRAINING	24
9	NOVEL USES OF MICROS	27
10	RECOMMENDATIONS	30
	APPENDIX 1 : PARTICIPANTS IN THE SEMINAR	32
	APPENDIX 2 : THE QUESTIONNAIRE	33

1 FOREWARD

In its five year life, the Microelectronics Education Programme (MEP) - in collaboration with schools, local authorities, universities and colleges, and with publishers and other commercial concerns - has produced a wide range of materials. Many teachers in secondary schools have already used these programs and devices as well as their supporting materials.

While so little has been known about the value of information technology for children in schools, it has rightly been a time for experimentation. Those who have had the confidence to get involved have tried out very diverse packages, some of which have worked well and others badly. Risks have been run but, in so many instances, the rewards have been high. There have been great surprises too. Those who have been involved have discovered a great deal about what can enhance and extend learning in their classrooms and beyond.

It is not easy to communicate all this experience, but it is timely now to try to consolidate what we can. Not all of the experience fits neatly into subject boundaries either, but we have recognised that it would be particularly valuable to encourage subject teachers in secondary schools to take a fresh view of the role and value of information technology in their work.

That is why we have asked many of the subject associations to bring together groups of experienced practitioners to discuss and report on the progress they have made. Each subject association has produced its own report and each has made a number of very important points about what is possible and desirable within its own realm. Together, the reports present a fascinating subject-by-subject appraisal of the place of, and prospect for, the new technologies.

Progress has been exciting and should be shared. I am very grateful to the associations for their hard work and cooperation in ensuring that, through these reports, even more teachers will learn about the real opportunities that now exist.

Richard Fothergrill
Director, MEP

2 SUMMARY

Computers are already widely established in science teaching and are making a contribution that cannot be matched in other ways. We believe it is an urgent priority for the government to make long term plans to maintain and protect the established capital base in schools as well as extending it.

We see that computers will be most productively and profitably used in the course of normal subject teaching and not as some separate aspect of education, and we see the most effective way of ensuring this as being to make computers available in the normal subject teaching rooms; we see this as particularly important in science teaching where one might want to link a practical experimental demonstration to a computer.

We see a long term need for computer use to be stepped up substantially in the initial training of teachers, but there is a very pressing need for more local INSET and more close at hand support for teachers who are struggling to make use of computers in their teaching.

We are appalled at the ad hoc, short term nature of existing planning by government and other central agencies, most particularly in the provision of software. Serious thought must be given to establishing long term security for software development.

The proportion of chemistry teachers who actually make use of computers as an aid to teaching and learning is disappointingly small. The overriding reasons for this have been identified as a lack of suitable software at prices that can be afforded, and computer hardware that is not available when it is needed.

We would like to see more use made of computers in introducing the economic and industrial aspects of the chemistry syllabus and especially to see an increased use of computers in data capture and control of experiments, aspects that are particularly relevant to chemistry, but which are shown to be exploited to a minimal degree.

3 SCOPE OF THE STUDY

In February 1981 the Government set up the Microelectronics Education Programme to promote the study of microelectronics and the use of computers as aids to teaching and learning. The five-year programme has now reached an end. As part of its planning for the future, the Department of Education and Science asked the Royal Society of Chemistry to investigate the current use of microcomputers and microelectronics in teaching chemistry at school level, and to advise ways to encourage and support future developments.

The current situation has been surveyed by a questionnaire to approximately 2000 chemistry teachers.

An expert seminar was convened with the following aims:

(i) undertake a critical review of the current uses of microcomputers in the teaching and learning of chemistry at the secondary level

(ii) identify areas of weakness in current provision and make recommendations to remedy these weaknesses

(iii) consider possible future developments and make recommendations concerning the further development of applications of micro-electronics to the teaching and learning of chemistry at the secondary level.

This report has been written with the help and support of the Education Division of the Royal Society of Chemistry.

Summary Results of Survey

Of 2000 questionnaires sent out, 613 were returned. 21 of these were outside the scope of the survey and so were excluded from the sample, giving a live sample of 592.

The questionnaire that was distributed is reproduced in Appendix 2.

The institutions responding were:

Maintained	268
Independent	99
6th form/tertiary	45
Colleges of FE	153
Unclassified	27

Of these 278 (47% of the live sample) were making some use of microcomputers in their teaching.

As a percentage of the institutions represented this figure breaks down as follows:

	No.	% of Sector
Maintained	122	46
Independent	49	49
6th form/tertiary	26	58
FE colleges	71	46
Others	10	37

Thus it can be seen that around half the institutions in each sector make some use of microcomputers in chemistry teaching.

Of those who used microcomputers in their teaching, 142 (51%) had attended a training course. The spread of training across the sectors is fairly even:

	No.	% of Sector
Maintained	74	61
Independent	20	41
6th form/tertiary	12	46
FE colleges	34	48
Other	2	20

Other responses suggested disappointing use of on-line information technology in the institutions responding, and we suggest some reasons for this in Section 9 'Novel Uses'.

It proved impossible to identify accurately from the questionnaire responses which software packages were the most popular, although few commercial packages seemed to be in general use, and much use was being made of self-written or otherwise unpublished programs.

A wide range of uses was described by respondents, although certain animation and drill-and-practice were the most frequently used program types. We were disappointed to learn how little use is being made of data capture and control of experiments, even though these would seem to be the most obvious uses of microcomputers in a chemical context.

We were disappointed to learn also that little use is being made of programs that allow students to prepare and test their own models.

These aspects of microcomputer usage are discussed more fully in Section 5 'Software'.

53% of respondents were not using computers in their teaching. The main reasons for this emerged from the questionnaire:

(i) Hardware: lack of availability of a computer where and when its use arises naturally in the course of teaching

(ii) Software: many teachers feel that there are insufficient programs of good quality available.

We discuss both these aspects further in Sections 7 and 5.

4 INTRODUCTION AND GENERAL CONSIDERATIONS

The use of computers in industry and commerce is becoming more and more widespread. It is desirable that children at school should become familiar with applications of computers and confident in their use. In the particular instance of chemistry, we believe that computers should only be used where they offer an enriching or enabling aspect to the teaching of the subject.

The two fundamental principles we recommend to guide the adoption of computer aided methods in chemistry teaching are:

(i) computers should only be used where they are genuinely the best resource

(ii) computer use should arise naturally from the laboratory/classroom situation; it should be a tool not an obsession.

It is important to recognise that computers are not the solution to all problems, and teachers must avoid the temptation to use computers simply because that is the fashion. We wish to encourage teachers to be extremely careful in their appraisal of software. They need to insist, of course, on the highest technical quality, but they must also assess whether a computer is genuinely the best resource for any given topic, and whether the design of the computer program offers an approach which suitably exploits the computer's facilities.

The particular usefulness of computers is entirely wasted if, with reasonable lesson planning, a computer is not available to the teacher when it is needed. Children should be made aware of computers by seeing their relevant use in the curriculum, and the impact will be completely lost if computers are used inappropriately or if pupils find the course of their lessons diverted because the computer cannot be available when it is needed.

Use of computers should enrich rather than confuse, and should also help pupils develop skills not solely concerned with chemistry.

Computer programs may be classified in a variety of ways. Some of these classifications refer to the subject matter of the program and some to the level of interaction with the user. One helpful hierarchical scheme has been described by Kemmis (S Kemmis, R Atkin, E Wright, 'How do students learn? Working papers on computer assisted learning', occasional paper No 5, Centre for Applied Research in Education, University of East Anglia, 1977); it classifies software into four groups:

(i) instructional: this includes drill-and-practice type programs and some non-interactive simulations

(ii) Revelatory: the computer acts as mediator between the user and a hidden model. The main use is in simulations where the user interacts with the computer in such a way that the underlying model is gradually revealed

(iii) Conjectural: programs such as 'Dynamic modelling system' or 'Animal game' which allow the pupil to construct and test hypotheses.

(iv) Emancipatory: programs that reduce the workload of the pupil. The computer takes over work that is not necessary to the work in hand (inappropriate labour), allowing the pupil to concentrate on the things that must be done as an integral part of learning the topic. This is sometimes referred to as 'noise reduction'.

We found the following non-hierarchical descriptions useful in considering the appropriateness of potential roles for computers:

(i) Simulation and Modelling - creating, questioning, manipulating

(ii) Noise Reduction

- removal of inappropriate labour
- simplifying study of processes, interactions etc

(iii) Provide More Experiences

(iv) Access to Information for Problem Solving

(v) Reducing Failure for Unnecessary Reasons.

Simulation and Models

There are many different approaches to simulation and modelling; and it is necessary to distinguish carefully between them. We found it particularly important to distinguish clearly between simulations of laboratory experiments and systems that allow pupils to build and test their own models.

In addition, simulations may have interactive and/or non-interactive elements in their construction.

Non-interactive simulations are probably better described as animations, and lend themselves to demonstration use by the teacher as an 'electronic blackboard'.

There are two main types of simulation of laboratory experiments, those duplicating the operation of apparatus (eg simulation of a burette) and giving 'practice' in its use, and those simulating a complete experiment such as Millikan's oil drop. Both the survey and the seminar were very critical of the simulation of a single piece of apparatus for the purposes of demonstrating operation and familiarisation of 'use'.

Many respondents to the survey felt very strongly that chemistry is a practical subject and resisted attempts to introduce computers into their teaching because they perceived the rise of interest in computers as a move to simulate as much as possible and thus remove laboratory work. We cannot support in any way the replacement of laboratory work by computer simulation.

Laboratory simulations that we would support include

- reactions or processes that are too fast, too slow, too dangerous or too time consuming to be practicable in normal laboratory work
- a simulation of an experiment which can be used on completion of a laboratory exercise as a quick source of <u>further</u> data which could not reasonably be obtained within the normal laboratory time allocation.

At present, most of the interactive simulations allow users to explore the variables in the model developed by the designer, and to hunt for patterns and laws. Programmers usually need to adopt simplified models, and the user is not encouraged to explore the validity of the model, nor to manipulate the model further either to refine it or to simplify it. We hope that developments in those areas will enable and encourage pupils to explore the models themselves and to realise their limitations.

Systems allowing pupils to develop and explore their own models are not numerous at present, although we hope to see this area exploited more in the future.

'Noise' Reduction

In too many areas of teaching the main point of the lesson can be obscured by a mass of detail, detail that may be necessary, for example, to get results from an experiment, but that is not necessary to the learning objective. The teacher knows the educational value of the exercise and does not see the surrounding detail as distracting. But the pupil who is attempting to hold a vast amount of new information in his or her working memory sees each detail or distraction as an overloading factor.

This situation can arise in expository teaching, where a confusing amount of detail might be given of, say, an industrial process, or in laboratory work where difficulties with drawing the relevant graph may divert attention from the object of the experiment. More efficient learning will take place if the 'noise' induced in this way can be reduced.

Diverting attention from understanding the course of a reaction to the problems of drawing a graph is an example of what we mean by 'inappropriate labour', although this should not be taken to mean that we consider graph drawing to be an inappropriate skill to develop as part of chemical education. However, suitable use of, for example, data capture and computer manipulation of results can allow pupils more clearly to see the point of the experiment they have just done. Without reducing the noise in this or some other way, the problems that pupils find in the means to the educational end can cause them to fail to grasp the objectives of the lesson - we consider this 'unnecessary' failure.

Providing More Experience

The seminar considered various ways in which computers can play this valuable role, and concluded that there were a number of possibilities. At one end of the spectrum a model of an experiment can be used after the experiment has been successfully completed in the laboratory to generate more results for further manipulation - in this instance the computer is allowing pupils to use a great many more results than they would be able to gather themselves during normal laboratory work.

At the other end of the spectrum, programs allowing role playing in economic or environmental situations permit chemical knowledge to be extended into more 'applied' contexts.

In addition, the reinforcement aspects of drill-and-practice programs could be considered as extending experiences through more extensive questioning than a teacher could reasonably manage.

Access to Information for Problem Solving Activities

Databases, both on- and off-line have great potential to reduce the difficulty of making information available in problem-solving activities, although we have some doubts about the short term usefulness of on-line information sources (see Section 9). The use of general purpose programs such as spreadsheets and databases for organising and manipulating data should be encouraged.

Reducing Failure for Unnecessary Reasons

Computer use for reducing failure can cover a range of possibilities. Excessive 'noise' has already been alluded to as one unnecessary source of failure. Lack of practice can be another where the patience of the computer can be invaluable.

At a simpler level the use of word processing with some pupils can overcome problems where presentation of results can give as much difficulty as understanding the concepts.

Software Guidelines

When assessing the curriculum and its implications for computers, the foregoing considerations were condensed to the following criteria:

- is the computer enriching or obscuring the topic?
- can other techniques be used more successfully?
- how appropriate is the computer according to the five-point model outlined above?

5 SOFTWARE

One of the guiding principles in the business computing market is that software sells hardware. Business clients first find a program or suite of programs that suits them and their approach to business; then they find a microcomputer which can run the software. In the education sector, the government funding of one specified computer or more for each secondary school has forced the opposite to occur. Schools had computers first and then had to find software to use on them. More government money was then given to software producers and publishers to fund development of educational programs, some of which have proved to be successful.

In spite of this many teachers responding to the questionnaire cited lack of available programs as one of the main reasons why they were not using computers in their teaching. There are currently over 80 commercially available chemistry teaching programs, but the exact figure is hard to establish. In spite of the apparently large number of programs, many respondents to the survey were unable to find software they considered suitable, or were disatisfied with quality or with previewing practices. Typical free responses to the questionnaire were:

> Few programs examined seem to be immediately usable for our A-level students without considerable modification... there is no on-approval arrangement before purchasing programs.
>
> ...though there are many programs available, it is not always possible to see on approval...
>
> ...I feel it better that my students study chemistry at first hand...
>
> I am not convinced of the value of computers in chemistry teaching and most of the programs I have seen are not especially impressive.
>
> I consider...that much of the time spent on computers (leads) merely to the development of keyboard skills.
>
> I have found little evidence that the 'teaching' programs are worth trying...the programs are often of a poor standard, 'crashing' easily and therefore not suitable for students to use on their own.

> I think there is too much stress on simulations - often at the expense of real bench chemistry.

The survey pointed clearly to two main short term needs. There should be a central clearing agency for software. Book publishers are required to deposit copies of their books in copyright deposition libraries. As a result of this and the ISBN system, it is possible for a potential purchaser to have a comprehensive picture of the books available in a given subject; anyone keeping a watching brief on new books on a subject can do so with reasonable expectation of success through the supplements to 'British Books in Print'. The same is not true at the moment of software.

Computer software is urgently in need of analogous systems. There is a need for a national library of software - a central agency to receive a copy of each program as soon as it becomes available, and with the responsibility to produce a 'software in print' publication which would be substantially complete.

This would greatly simplify the process of finding programs, but it would not address the problem of whether or not the programs are suitable. To find suitable programs a thorough reviewing system is required.

Present reviewing practices centre on reviews of products by individual reviewers, in a system analogous to book reviewing. Many educational publications attempt to review software in this way, but they are hampered by the unwillingness of some publishers to provide review copies of their programs - presumably for fear of illicit copies being made. This type of individual review is useful, but is probably less suitable for software then for books because of the greater variety of possible ways of using a computer package. Journals will undoubtedly continue to review software, and publishers should be encouraged to exploit the reviewing system as they have for books.

We felt that a joint review by a small team of reviewers working together produced a more balanced and helpful assessment. This is a fairer approach because it makes allowance for differences in teaching styles.

Such a reviewing system could be organised, and the reviews suitably publicised if subject associations (in the case of chemistry, the RSC) would, in conjunction with the ASE, organise reviewing panels to work systematically through the existing software base and then keep pace with new software developments and produce and make available team reviews.

One of the less rewarding observations from survey responses was that there is a body of teachers that seem to want software to do what they already do, and to do it in a similar way. Software to satisfy this type of teacher will be content-loaded and will not fulfil the main educational requirement that the computer should only be used when it is the best resource for the application.

We believe that the greatest potential use for microcomputers is in developing skills that are not particularly content-related.

Poor software has a demotivating effect. Even 'good' software can be demotivating if it is used with little understanding and in unimaginative ways. Inadequate hardware, or computers not available when required are also highly demotivating. However, we recommend that, in cases where development funding is limited, software should take priority.

Current Areas of Weakness in Software Provision

Publishers are wary about providing inspection copies of software in the same way as they do for books, largely because of the fear of illegal copying. This deters many teachers and they are unable to assess software as they would any other resource; funds are not available to purchase software unseen and untested so software is not bought. Publishers undeniably have potential problems with piracy, or at least illegal copying, but until inspection copies are made available in the same way as for books some teachers will not purchase software.

Chemistry teachers have a right to expect certain things from computer programs. First, and most important, the program must operate without 'bugs' that will cause it to break down without possibility of easy recovery. It must be easy to use, with a clear and logical control sequence. Standards of text and formula presentation in the printed word are high, and teachers can reasonably expect similar information to be presented on a computer screen to the same high standards.

Business programs make extensive use of 'help menus', and this facility could usefully be incorporated in many educational programs.

The authors responsible for the design of educational programs usually have a clear concept of the teaching and learning strategies that were intended, but this information is seldom communicated to the potential user. Most documentation deals mainly with the technique of loading the software.

Considering that data capture is one of the most frequently discussed areas for chemical computing, it is surprising that so little software has been developed to give an easy introduction to the technique.

Software seems to be most appreciated in less traditional topics where resource material is less easily obtainable, hence there is an interest in industrial simulations and programs such as blast furnace siting. This could provide a focus for further software development. Industry should be persuaded to sponsor software development in this area of the syllabus.

Recommendations for Software Developments

It is in the interests of teachers, publishers and central agencies to promote and develop good software. The price currently paid for each educational software package (in the range £10-£30) is regarded by the publishers as the highest that the market will stand, and by most teachers as too high. It is, however, an order of magnitude smaller than the current prices for business software. The price restriction, together with the smallness of the educational market, means that there is no possibility of commercial agencies taking over the development of software - the development costs would never be recovered, without additional funding.

The two most likely sources of future software are the cottage industry approach, in which individual teachers publish their own programs, and the funded development projects such as that at Chelsea College (now KQC).

The cottage industry approach poses problems of quality control and duplication of effort. The greatest success to date has occurred when a publisher has taken on the task of presenting third party software in a uniform format (eg Pitman, AVP) or where an LEA has sponsored a computer user group.

It is probably true to say that the most successful software to date has been produced by funded projects. The overall guiding influence of the MEP in avoiding duplication of effort has been an important feature of this success. The present, short-term, ad hoc funding of such projects is far from satisfactory. It takes a considerable time for a group to develop a working style and build up technical expertise. If projects run only for one or two years these skills are dissipated just when they should be beginning to pay dividends.

Funded projects require some long-term staffing, to maintain expertise, particularly in program coding. The design side, however, may be best staffed by teachers on part-time or short-term release so that contact with classroom practice is not lost. Careful consideration will be needed to find ways of allowing the teachers concerned a reduction in their normal teaching load without causing resentment among other staff.

6 SOFTWARE AND THE SYLLABUS

The National Criteria for Chemistry were used as a guide in assessing the provision and possibilities at the pre-16 level, and the London A-level syllabus for the post-16 level.

At both levels we found areas which were already well provided with computer software, and where we could not recommend further effort be expended. Some topics we were unable to recommend as suitable for computer applications. We also found areas which could be taught with the aid of suitable software, but where software had yet to be written.

We give examples of some of these areas below, although we do not wish these suggestions to be taken as a definitive statement of potential areas for development. In a technique with such a variety of approaches, we did not see it as part of our brief to restrict innovation in any way, and we hope that naming such a list will not deter software authors who succeed where we failed to find valid ways of using computers to help to teach some topics.

The criteria that were used and our interpretation of them have already been discussed (see Section 4) and when assessing the curriculum and its implications for computers, these considerations were condensed to the following:

- how appropriate is the computer?
- is the computer enriching or obscuring the topic?
- can other techniques be used more successfully?

Courses to 16 (Numbering refers to National Criteria)

Experiments (4.1)

In the context of this section of the national criteria we saw little potential for using computers in developing skills which are best developed by using real apparatus in real situations, thus we were unable to recommend computer use in manipulation, observing or measuring, although general programs for graphing results might be applicable as an aid to interpretation. Once manipulative skill has been developed, computers can be used as part of normal practical work.

Elements and Compounds (4.2)

Programs to give practice in balancing equations already exist as does drill and practice software on properties of elements.

Ideas, Models, Patterns and Theories (4.3)

This is a wide topic which, in general, is suitable for computer uses. Many programs exist dealing with pH, acids, bases and salts, the periodic table etc. In general we would like to see more programs to help to develop the skills of classification and investigation and hypothesis testing at this level. We were aware of some programs that had been written in the area of energetics, reversible reactions and oxidation and reduction, but we felt these to be only marginal areas for computer application.

Chemistry in Industry (4.4)

We felt this section to be one of the most suitable for computer applications, especially simulations. There are already a number of simulations dealing with, for example, the production of ammonia, sulphuric acid and the siting of blast furnaces and aluminium plants. Software seems to be particularly valued in this area by teachers because it fulfils functions not possible in textbooks, and teachers are less sure of the industrial areas than other topics. There is still scope for further development.

Social, Environmental, Economic and Technological Application of Chemistry (4.5)

We recommend that the computer, through its potential for simulation and role-playing applications, is especially suited to introducing and increasing pupils' awareness of the social and economic aspects of chemistry. However, we do not recommend that specific programs be written solely with the intention of dealing with this topic, but rather that the computer should be used as a linking and enabling tool to introduce social and economic aspects to other, more 'theoretical' parts of the syllabus, through simulations and models involving environmental and economic aspects.

Courses post-16 (Numbering refers to London A-level syllabus June 1986/Jan 1987)

The main areas with potential were seen as being those applying to problem solving and organising chemical knowledge.

Atomic Structure (2)

There is potential for simulation, demonstration and display ranging from mass spectrometry to representation of orbitals.

Ionic Bonds (3)

Particular potential uses are in displaying arrangements of ions in three dimensions, and shapes of bonds.

Energetics (4)

Potential applications were recognised in Hess's Law and enthalpies of formation and reaction. Some software is already available in these areas.

Gaseous State (5)

Potential uses in modelling ideal gases and in graphically representing the distribution of velocities in a gas.

Phase Equilibria (6)

Demonstration of principles of fractional distillation.

Chemical Equilibria (7)

Modelling of the equilibrium state and clarifying le Chatelier's principle, redox equilibria and pH.

Rates of Chemical Reaction (8)

Rates of reaction were felt to be more suitably dealt with by computers at the post-16 level than the pre-16 level.

Chemical Periodicity (9)

Potential for use of database programs for study of periodic relationships.

Main Group Characteristics (10)

Main potential in identifying and demonstrating trends.

Structure and Reactivity in Organic Compounds(12)

Potential for better study of reaction mechanisms.

Chemistry of the Functional Groups (13)

Mechanisms, petroleum distillation and cracking.

Industrial Chemistry (14)

As with the pre-16 syllabus, we believe that industrial aspects are important, but that they should be integrated with the rest of the syllabus. In this approach the computer is probably the best resource to introduce and exploit these connections.

7 HARDWARE

In 1982 the Department of Trade and Industry (DTI) made money available in a scheme designed to ensure that each school in England and Wales had at least one microcomputer. Money was distributed in a pound-for-pound grant scheme and, for secondary schools, only two microcomputers were eligible, the Research Machines 380Z and the then new BBC Microcomputer. At the time this did not please those schools that had, through their own resources, already bought Apple II or Commodore Pet computers, but it did succeed remarkably in focusing the minds of software writers and publishers and resulted in establishing an extensive software base.

In the time since this initiative took place, there have been great changes in the business computing market with dramatic increases in the capabilities of computers. New 16-bit computers have replaced the earlier 8-bit models. The IBM PC has set new standards in compatibility of business software. Computers now have increasing amounts of memory available at realistic cost, and the capabilities of storage through hard or floppy discs have increased almost as rapidly as the costs of the units have fallen. It is unlikely that this progress will cease in the near future; this places a great responsibility on those formulating recommendations for replacing existing hardware in schools.

The existing computers in schools are already showing signs of age. Disc drives develop faults. Printers need replacement parts. The main thing that is needed to get the best out of the computers that are already in schools is money and facilities for maintenance. The need is urgent.

The initiative to place a microcomputer in every school has opened the eyes of many to the possibilities. There is a need now to extend the number of computers in schools and to ensure that machines are available when required. Many of the computers currently in schools are looked after by the maths or computer studies departments; this severely limits use in the laboratory or for data capture, although there are applications of high potential in chemistry teaching. One of the main reasons cited by teachers who would be interested in using micros for not doing so was that a micro was not available when they needed it.

Ideally we should like to see a computer available in every science laboratory, but we feel that it is more realistic to suggest a minimum provision that a computer should be available to every chemistry teacher when its need arises naturally out of the curriculum. It is not sufficient to

recommend that optimum use be made of booking systems, as this is contrary to our aim to see the computer as a natural resource to be used as it arises in the normal course of teaching. Peripherals such as disc drives and printers must be made equally freely available.

The third major area where action is necessary is compatibility. The computer industry usually considers the problems of upward compatibility; future plans for computer facilities must take account of possible future developments, and it is important that future microcomputers used in education are able to make use of the existing software base. But for the schools 'downward' compatibility is also important. As there is already an extensive hardware base which will need to remain in use for some time to come, software and hardware producers should be encouraged to ensure that as much of the hardware and software as possible remains compatible.

Regarding actual developments in hardware, educational users will be seeking:

(i) better graphics,

(ii) faster, 16-bit computers, and

(iii) greatest possible compatibility.

We wish to see a coherent plan for maintenance of existing hardware, replacement of units as repair becomes uneconomic, and a general increase in the level of microcomputer and peripherals provision in schools.

8 IMPLICATIONS FOR TRAINING

Many of the teachers surveyed claimed to have little confidence in using microcomputers, even though 51 per cent had been on training courses of one kind or another.

One of the problems in persuading more teachers to use microcomputers in their teaching is that many do not see the micro as simply one of a range of resources, instead they react violently against the 'threat' of computerised teaching. This response is by no means confined to those unfamiliar with computers.

Attitudes

Typical free responses in the survey were:

> Nearly everything that a computer can do in chemistry teaching can be done as well, if not better, by a film or videotape, a book or a teacher and blackboard...(computers are) amazingly useful and versatile in the right place - but not in chemistry teaching.
>
> I suppose a micro with teaching programs could be useful for engaging the attention of 'illiterate thickos' with very low powers of concentration on the written word.
>
> I am suspicious of the use of computers at school level for teaching principles.
>
> If a choice has to be made between using a computer program and carrying out a practical experiment, I consider the latter is definitely preferable.
>
> ...an awareness of microtechnology is essential but its use as a substitute for teaching including program learning is not in my view helpful.
>
> I believe that most pre A-level chemistry is best taught by time in the lab - not by simulation.
>
> ...large resource of money and time could be expended in order to justify the computer when the same teaching job could be done more quickly and efficiently by traditional laboratory work.

A significant number of teachers - whether they were confident about computers or not - weren't using computers because they felt that there were no suitable programs or because a computer was not available when it was needed.

The experience of the participants in the seminar, and largely supported by the results of the survey, was that where micros were currently effectively used it was as a result of the presence in the school of a committed, enthusiastic teacher. In any thorough planning of computer resources for schools, the ideal of ensuring that at least one knowledgeable and enthusiastic teacher is present in each school should be taken seriously. In addition, thought must be given to developing the abilities of all teachers, both interested and uninterested.

The crux of the problem was felt to be teaching and learning styles. Computers allow for individual teaching and learning styles, but computer use seems to be less compatible with certain styles. More effective use could be made of micros if teachers were encouraged, during their initial training to make more use of alternative styles. For example, some teachers dismissing computers as teaching aids claim they will be of no use because there are not enough available for pupils to have one each - yet many teachers succeed in giving all their pupils experience of computer use by using a computer program as part of a circus of practical work, or by using it as a demonstration tool. These varied styles need to be explored further.

Another paradox in some teachers' 'requirements' for software relating to teaching styles was highlighted by comments in the survey. If programs are written to help teach a certain area of the syllabus, teachers will say 'we have been teaching this topic for years without the help of microcomputers, why should we use them now?' Alternatively, if programs are written developing topics that are not on the syllabus, teachers say 'we have no time to deal with topics that aren't on the syllabus'!

One of the main problems facing the beginning user of software is how it can be used in the classroom or laboratory. There is a great need for propagation of good practice, and a manual of good practice together with a video showing examples of teachers using software successfully should be prepared. Such a resource would be very useful, but we emphasise that the techniques in any such collection should be seen only as examples; they should not in any way restrict development of new methods.

Most software is not intrinsically 'good' or 'bad'. A program that one teacher can find no use for can be a very useful tool in the hands of another. The success of any program depends on the method of use, and so experience of various types of software and guidance in its use is important at all stages.

In-service Training

In-service work will need to be sustained and developed, especially as new developments take place in microcomputer hardware. In particular there is a need for whole departments to be able to work together as teams to develop new approaches within existing curricula.

In addition, there will be an increasing need for group work in science, so general INSET on working in groups will be increasingly needed in the future.

One of the main problems facing INSET will be in persuading teachers to use microcomputers sensibly. One observed problem is that once teachers have developed an interest in computers they are likely to start specialising in computing, ultimately becoming computer studies teachers rather than chemistry teachers.

INSET will need to concentrate on educational issues, to move away from trying to make programmers out of teachers and to focus on making optimum use of the computer as a teaching aid.

Local user groups are a good way of disseminating information. There seem to be two main sorts, the subject-specific groups and the more general. Some groups are run through LEAs and others by enthusiasts. User groups have an unparalleled potential for 'self-help' and for sharing experiences and problems, and they should be actively encouraged. A suitable model might be to encourage LEAs to devote their efforts to the larger groups that are not subject specific. Subject associations could then take responsibility for supporting and coordinating subject-specific groups.

Initial Training

For student teachers to be aware of microcomputers and able to use them effectively, they should be introduced to them in two ways during their training course. Use of software as an educational resource in the classroom should be covered in the course of normal training, and also as part of teaching practice. In addition, trainee teachers would have more confidence in the resource if they saw it being used by their own course tutors.

No teacher is fully equipped for teaching on leaving college, and he or she will continually need to assess new resources as they develop. Evaluating software is a difficult task and one in which the trainee teacher needs guidance. In order to ensure appropriate use of resources, training in evaluation and reviewing should be given for books, video materials and any other teaching resources. This recommendation might require a research project to be funded in order to establish assessment criteria, techniques and good practice.

9 NOVEL USES OF MICROS

We were grateful for the opportunity to explore some of the possible future routes for use of computers in schools. Some of the anticipated developments were felt to have less potential for success than seems to be currently supposed.

The firmest prediction was that new uses of microcomputers and microprocessor-based equipment in the education system would only develop sensibly if properly researched and evaluated. Research into new techniques must be funded, and the outcomes of any new ideas proposed must be carefully assessed.

Electronic Communication

Money is currently being made available to place a modem in every school. The presence of a modem means that each school will be able to contact on-line databases such as Prestel and The Times Network for Schools, and make use of electronic mail. Implicit in this is that pupils should have the opportunity to experience the world of electronic information at first hand.

We doubt the potential for modems and electronic communication in schools, and in particular doubt the prospects for pupil use of these facilities. In areas where experiments of this type have been tried, telephone costs have proved to be high and in the current climate of insufficient educational funding high telephone bills are a luxury that LEAs can ill afford. We do not doubt the potential use of electronic communication in business, but doubt that current funding can accommodate its use in schools.

The survey showed only 78 (28%) institutions making use of on-line techniques. This represents 23% of the non-FE sample and 40% of the FE sample. The on-line service most subscribed to in both sectors was Prestel, with the Times Network for Schools ranked second in the non-FE sector. Even so, the Times Network for Schools which has been specifically designed for educational uses is subscribed to by only 8% of the schools and sixth form and tertiary colleges represented in the responses to the survey.

Present patterns of use should be examined more fully before more resources are committed to this technique.

One aspect of electronic communications viewed by some as being of great utility to teachers is the idea of resource materials being available on-line. The idea of being able to connect to a remote computer with a database of resources, select relevant materials through a simple

keyword search and transfer 'ready-to-use' worksheets via the telephone line to a computer in a school ready to be copied and distributed to a class is initially seductive. This type of delivery system is seen in some quarters as the ideal way of making material easily available to a large number of teachers.

Unfortunately, it is also necessary to consider the problems of the approach. While it is true that worksheets 'downloaded' as described can be edited or rewritten by the teacher to suit his or her style of teaching, the product remains a computer printout with all the graphics limitations that go with it. Indeed, many teachers will feel that the effort of editing or rewriting is hardly worthwhile and will opt instead to write their own materials as they have frequently in the past.

Although this sort of delivery system may prove ultimately to have advantages, particularly when the graphics qualities of printers have improved sufficiently, it should be carefully investigated as it develops lest costly investment be made in systems that do not meet teachers' requirements.

We agree that it is early days for electronic communication and that the growth curve is still steep, but the system at present has more problems than currently appreciated.

Interactive Video

The conventional stance on interactive video - especially interactive videodisc systems - is that it has the greatest potential for teaching systems so far devised. The combination of moving or still pictures with or without computer graphics, controlled by easily-prepared interactive programs is as near to ideal as many of the proponents of computer managed learning have managed to conceive. But then the idealism stops and realism begins as the costs are discussed and it is realised that the playing equipment alone will cost several thousand pounds.

Discussions at the seminar began to develop along similar lines until we became aware that the Domesday project, organised by the BBC, has involved a great many schools in a great deal of exciting project work. For this reason, it seems likely that support groups such as parent teacher associations might be prepared to make suitable equipment available in schools in greater numbers than the costs involved would suggest.

The other main stumbling block universally recognised is the cost involved in preparing a videodisc suitable for use

with interactive teaching software. Some funding has already been made available for the preparation of experimental discs. A chemistry disc should be funded, to be used with hardware suitable for schools, and with the capability for interactive packages using it to be written in a 'cottage industry' fashion.

Expert Systems

In essence, an expert system is an attempt to encapsulate enough of the knowledge and experience of an expert in a particular domain to be able to obtain, from given data, answers similar to those that the expert would have given in person. The most usual implementations use an approach in which the expert system elicits the data it needs interactively. There are many ways of representing expert 'knowledge', but the most common at the moment is a system based on 'if...then' rules. The expert system will then use these rules via an 'inference engine'. An important part of expert systems as currently defined is the facility to ask the system for an explanation of why a particular question has been asked, or a rule invoked.

Expert systems are a spin-off of the early days of artificial intelligence research, and the first systems were tailor-made for each application in languages such as Lisp. However, the mechanism of the expert system was soon recognised as being domain-independent, and expert system 'shells' were one of the first aspects of articial intelligence research to be commercialised. A shell usually consists of the user interface and the inference engine, together with a method of producing rules in such a form that the inference engine can operate on them.

As expert systems encapsulate knowledge in specified domains, and permit users to ask questions of the 'expert', we believe that there could be potential for expert systems use in teaching and that this potential should be explored. Funds should be made available to allow proper evaluation of the possibilities; such an assessment should include input from practising teachers.

Research and Assessment

Whatever the new directions may be for computer use in schools, they should be the result of positive action. We recommend that research groups be established to look into new possibilities as they arise and to make recommendations as necessary. A second, and possibly more important thread in long term planning is that all new techniques adopted should be monitored to assess the effects. Monitoring groups should also be established.

We believe it to be especially important that practising teachers are active in these groups.

10 RECOMMENDATIONS

General

* Computers should only be used where they are genuinely the best resource.

* Computer use should arise naturally out of normal teaching and in the normal place of teaching.

To the DES

* A complete plan is necessary for the maintenance of the existing hardware base and replacement of existing units as repair becomes uneconomic.

* For chemistry teaching to benefit from microcomputers there must be a general increase in the level of provision of microcomputers and peripherals in schools.

* Funding is needed for a national library of software.

* Funding is needed for the continued development of suitable software.

* New uses of microcomputers should be investigated through establishing and funding research groups.

* Funding should be made available for preparation of a chemistry videodisc suitable for interactive video applications.

To the Association for Science Education and the RSC

* Develop a system for obtaining and publishing team reviews of software.

* Establish and promote local user groups specialising in chemistry teaching software.

To Teacher Education Bodies

* Use appropriate computer software as part of chemistry teaching on courses.

* Include assessed course work on the use of computers.

* Ensure that students have opportunities to use computers with pupils during teaching practice.

* Encourage students to use a variety of teaching styles.

* Include training in evaluating resources.

To Software Producers

* Technical standards of programming must be high.

* Standards of text and formula presentation must be as high as they are in books.

* More use should be made of 'help' menus.

* Documentation should include information about the intended teaching and learning strategies.

* Treat software more like books and provide teachers with inspection copies of software when requested.

* The possibilities for computers in emphasising the industrial, social, technological and environmental aspects of chemistry throughout the syllabus at all levels should be explored.

* Exploit the possibilities for laboratory capture of data.

To Teachers

* Do not use computers if other resources are better for teaching a particular topic.

* Explore the possibilities of using general purpose software as a tool in chemistry teaching and learning.

* Insist that software is of the highest quality.

* Respect software publishers' copyright and do not abuse the privilege of inspection copies.

* Seek out local user groups and use them.

* Insist that a computer is available when its need arises naturally.

To Industry

* Support development of enterprising software in your area.

APPENDIX 1 : PARTICIPANTS IN THE EXPERT SEMINAR

Ms C Adams (Newlands School)
Mrs A Brown (Queens' School, Bushey, Hertfordshire)
Dr P E Cattermole (Winchester College)
Mr R Dorrance (Science Adviser, Berkshire)
Mr J Freeman (North London Science Centre)
Dr M Linington (Science Adviser, Merton)
Dr R B Moyes (University of Hull)
Dr J D Murdoch (Graeme High School)
Dr P E Nicholson (University of York)
Dr J P Oversby (Stokesley School)
Mr G Slightholm (HMI)
Mr M J Withers (Royal Society of Chemistry)

APPENDIX 2 : QUESTIONNAIRE

ADA/kaf(84)
15 September 1986

ROYAL SOCIETY OF CHEMISTRY

THE USE OF MICROCOMPUTERS IN CHEMISTRY TEACHING

Please complete and return using the enclosed reply paid envelope to arrive **by 21 February 1986.**

Please tick box(es) or write responses in spaces provided as appropriate.

1. Training

a) Have you been on an inservice training programme on the use of microcomputers in teaching? YES ☐ NO ☐

b) If yes, how long was the course?

part-day ☐ whole day ☐ longer ☐

c) If no, would you like to receive training if it were available? YES ☐ NO ☐

2. Use

a) Do you use microcomputers in teaching chemistry? YES ☐ NO ☐

b) If no, is this because: YES NO

(i) the computer is not available when you want to use it? ☐ ☐

(ii) suitable programs do not exist? ☐ ☐

(iii) you do not like using computers? ☐ ☐

(iv) you do not think computers are useful teaching aids? ☐ ☐

(v) they do no repay the time spent ☐ ☐

c) If your answer to 2b(iv) was **YES** could you please say why you think computers are **not** useful:

.....

.....

.....

If you answered **NO** to 2a), please turn to the last page and complete questions 10 onwards. If you anwered **YES**, please move on to question 3.

3. Expertise

How confident are you in:	very confident	confident	not confident
a) using microcomputers?	☐	☐	☐
b) programming in basic?	☐	☐	☐

cont/.....

4. Support

a) If you have any problems where or to whom do you turn for help?

.....

b) Do you belong to a local group interested in educational applications of microcomputers? YES ☐ NO ☐

5. Equipment

a) Types and numbers of computers: Please enter into the appropriate cell(s) on the grid the numbers of computers you use in chemistry teaching, showing their type(s) and location(s) in your institution:

	In your lab.	In your dept.	Elsewhere in Institution
Rm 380Z/480Z			
Nimbus			
BBC			
Apple			
Apricot			
Sinclair spectrum			
Sinclair QL			
IBM			
Commodore PET etc.			
VELA			
Others, please specify:-			

b) Loading programs: How do you load programs?

using a disc drive/microdrive? ☐
using a cassette recorder? ☐
using a network? ☐

c) Monitor: What sort do you normally use?

colour ☐ monochrome ☐

d) Printer: How easily do you have access to a printer?

none ☐ with difficulty ☐ easily ☐ always attached to the computer you use ☐

e) Networks: Do you have a network? YES ☐ NO ☐

6. Information Sources

a) Does your institution subscribe to:

b) If yes, indicate use made:

	NO	YES	Searching for information	searching/ receiving messages	down loading software
Prestel	☐	☐	☐	☐	☐
TTNS	☐	☐	☐	☐	☐
Other, please specify	☐	☐	☐	☐	☐

7. Uses made of computer

a) What do you use a computer for:

		Age range/course 11-14	CSE	O level	A level
Management:	data files	☐	☐	☐	☐
	word processing	☐	☐	☐	☐
	spread sheets	☐	☐	☐	☐
Simulation:	animation of theoretical concepts	☐	☐	☐	☐
	laboratory experiments	☐	☐	☐	☐
	industrial processes	☐	☐	☐	☐
Motivation, e.g. adventure games		☐	☐	☐	☐
Drill and practice		☐	☐	☐	☐
Data capture		☐	☐	☐	☐
Data processing		☐	☐	☐	☐
Control of experiments		☐	☐	☐	☐
Modelling using students' model		☐	☐	☐	☐
Other uses (please specify)		☐	☐	☐	☐

b) Mode of use: For each age range/type of course, indicate how you make use of the computer:

	with whole class under teacher control	by small groups of students under student control	by individual students
11-14	☐	☐	☐
CSE	☐	☐	☐
'O' level	☐	☐	☐
'A' level	☐	☐	☐
Others, please specify:	☐	☐	☐

cont/....

8. Software

List below the software you use and the age range/course for which it is used. You should include published and unpublished programs. Place an asterisk (*) against the **three** programs you find most useful.

Title	Author if known	publisher/ source	Age range/course 11-14	CSE	O level	A level
			☐	☐	☐	☐
			☐	☐	☐	☐
			☐	☐	☐	☐
			☐	☐	☐	☐
			☐	☐	☐	☐
			☐	☐	☐	☐
			☐	☐	☐	☐
			☐	☐	☐	☐
			☐	☐	☐	☐

(Continue on separate sheet if necessary)

9. Future Development

a) List **three** subject areas in which you would most like to see programs developed:

	11-14	CSE	O level	A level
	☐	☐	☐	☐
	☐	☐	☐	☐
	☐	☐	☐	☐

b) List the subject areas which you think are least appropriate for development:

10. Type of institution

Indicate the type in which you teach:

maintained school	independent school	sixth form/tertiary college	college of FE
☐	☐	☐	☐

11. Personal computer

Do you own a personal computer?

YES	NO
☐	☐

12. Name and address

As we may wish to contact you again, we should be grateful if you could give your name and address. This is, however, not essential:

NAME .....

ADDRESS .....

.....

.....

Thank you for your help

A D Ashmore